Using Real Time Kinematic GPS and LIDAR to Survey Outer Cape Cod's Changing Coast

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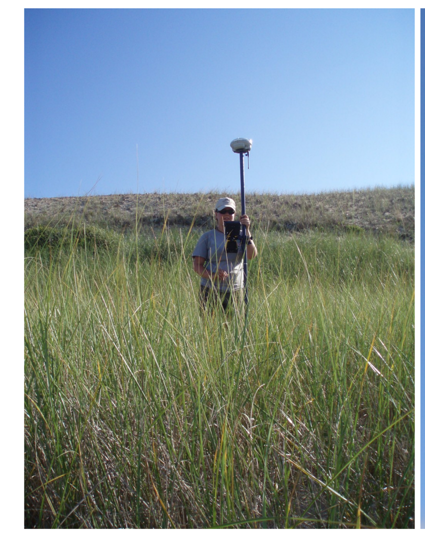
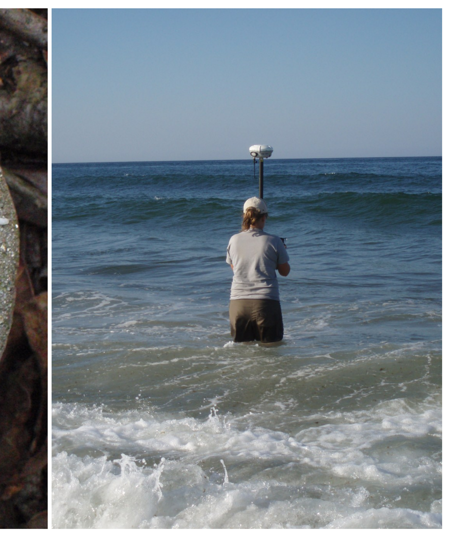


Surveying a Marindin Profile in dune grass

Trimble R8 GNSS Receiver

Surveying a Marindin Profile in Nauset Marsh

A survey benchmark where the base station is set up



It's a tough job but someone has to do it!

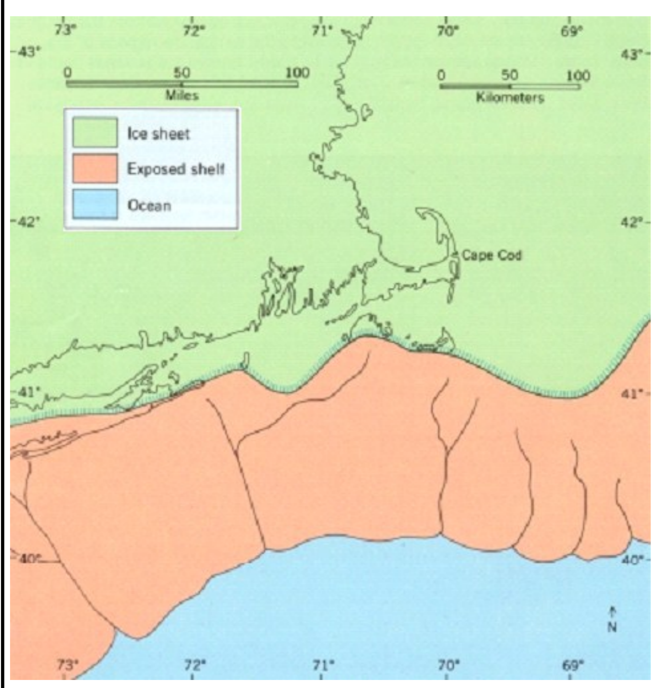
Abstract

Cape Cod formed from glacial sediment deposited on the exposed continental shelf when the Laurentide Ice Sheet retreated around 18,000 years ago. As sea level rose, wave action eroded the shore line along Cape Cod and transported sediment forming the Provincetown Hook and the barrier islands in Chatham.

Cape Cod has a 125 year record of measured coastal change. From 1887 to 1889, Henry Marindin of the U.S. Coast and Geodetic Survey measured the elevation of 229 coastal profiles spaced at 300 -meter intervals from Chatham to Provincetown. The lines were surveyed from onshore points across the dunes, bluffs, and beaches and continued offshore for 1-2 km.

The current monitoring study is resurveying 35 of the original profile lines to track changes along the coast. The profile lines were chosen because of their position near park infrastructure and historical or natural resources. Two elevation data collection methods are being used and compared: RTK GPS and LIDAR. The logistics for doing a RTK Survey in challenging terrain require creative solutions for getting to remote sites and using a base, rover, and radio repeater to increase the surveyable area. LIDAR offers more comprehensive coverage but lower accuracy. Results will be used to test long-term monitoring methods for seasonal and multi-year coastal change and will be critical to sustainable management of infrastructure and coastal ecological habitats.

Geologic Context



The maximum extent of the Laurentide Continental Ice Sheet 23,000 years ago. Cape Cod, Martha's Vineyard, and Nantucket formed from moraines and outwash plains that were deposited when the Laurentide Ice Sheet paused during its retreat about 18,000 years ago (Oldale, 2001).

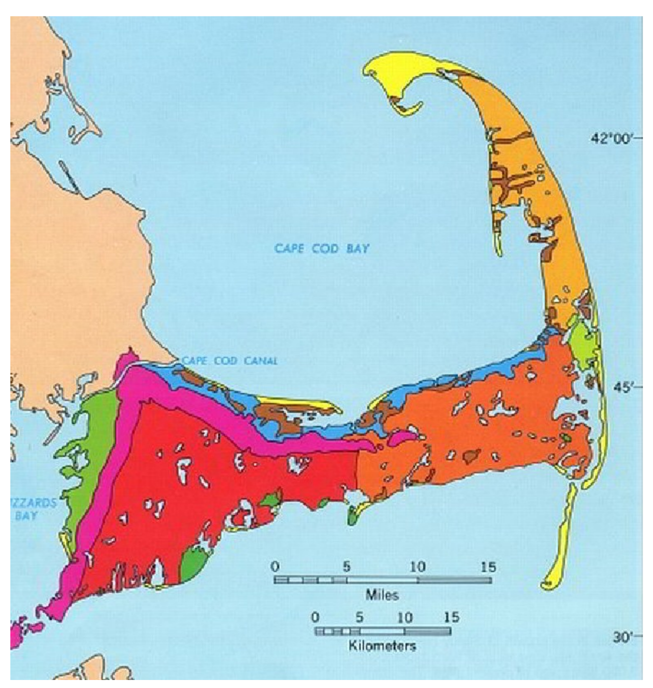


Figure 1 shows a generalized geologic map of Cape Cod. The yellow areas formed from reworked glacial deposits. Wave action erodes outwash plain deposits and sediments carried by longshore drift formed Chatham, Monomoy Island, and Provincetown Hook. The erosion and transportation of sediment continues today (Oldale, 2001).

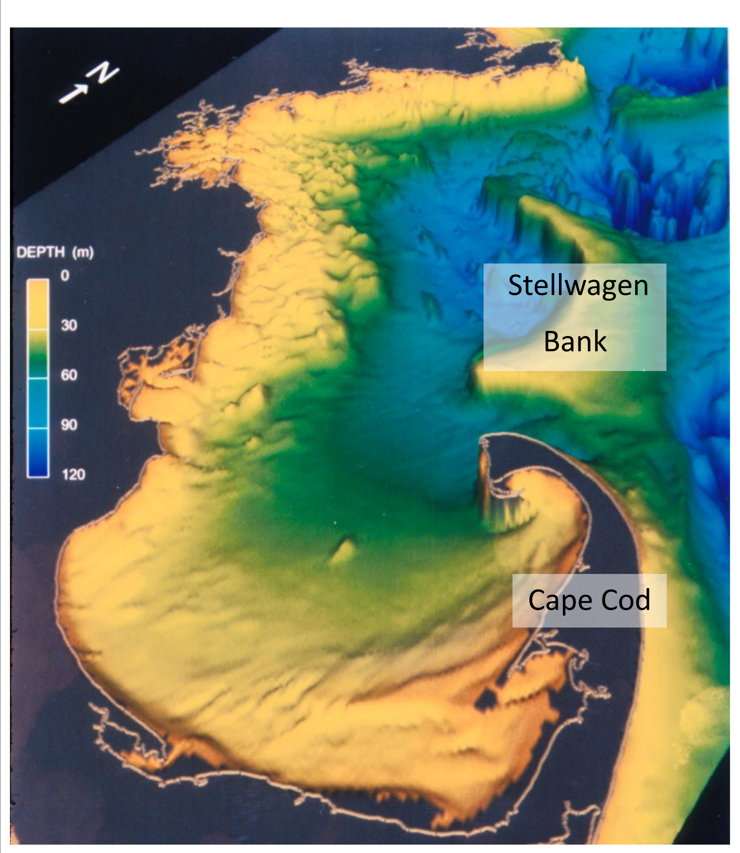


Image Source: NOAA, 2005

The Laurentide Ice Sheet outwash deposits and moraines also formed Georges Bank and Stellwagen Bank. It took approximately 17,000 years for rising sea levels to inundate those landmasses, transforming them into marine habitat and productive fishing grounds, which supported New England's economy. If sea level continues to rise at its current rate Cape Cod too could become completely submerged forming "Cape Cod Bank" in about 18,000 years.

Marindin Profiles: Then and Now

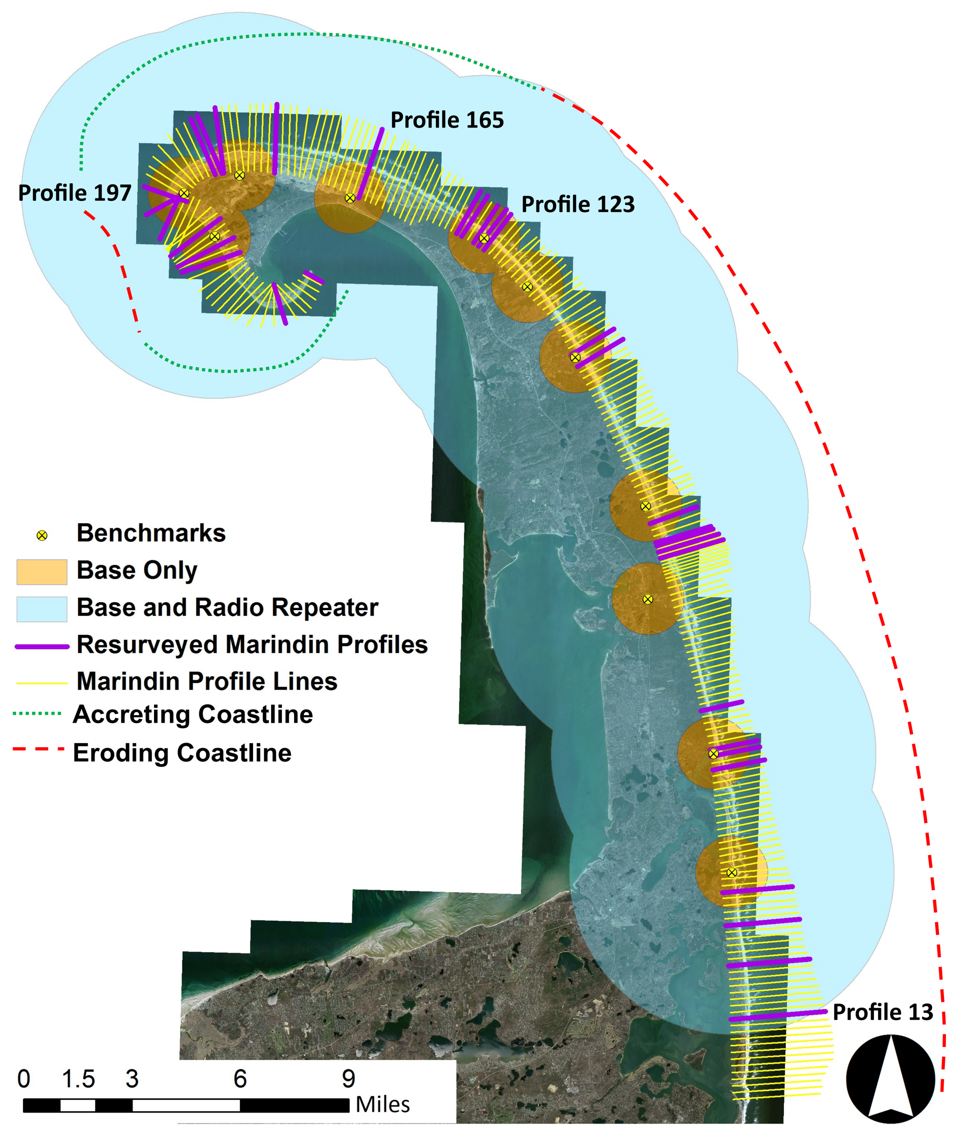
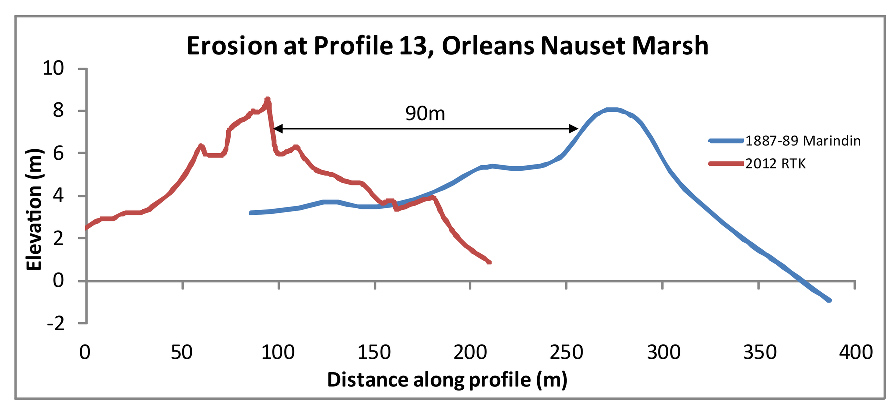
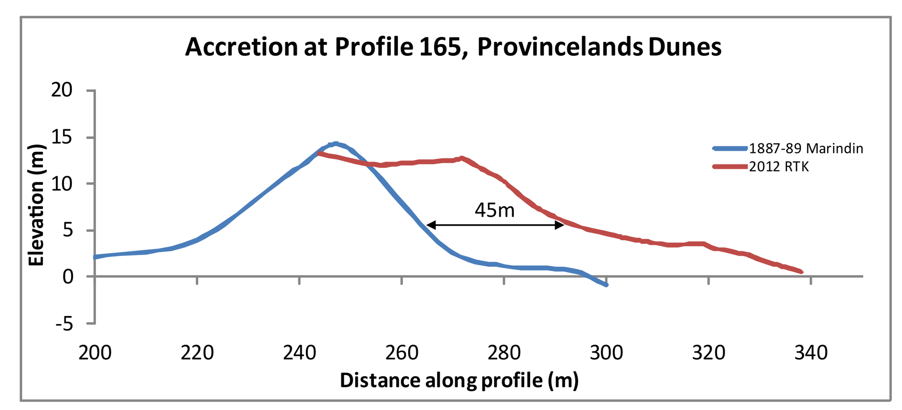


Figure 2:
From 1887 to 1889, Henry L. Marindin of the U.S. Coast and Geodetic Survey surveyed 229 profiles from points onshore across the dunes, bluffs, and beaches, and continued offshore for 1-2km. These surveys are a valuable baseline for current monitoring research.

As part of the Northeast Coastal and Barrier Network Geomorphological Monitoring Protocol, 35 of the Marindin Profiles were selected to be resurveyed using RTK GPS based on their location near park infrastructure such as lighthouses, bathhouses, and parking lots.

The best arrangement for surveying was to use the base station and a radio repeater. Together they increased the survey area and decreased the number of benchmarks needed to complete the surveys.





Comparing the Marindin elevation data with the 2012 data shows a changed coastline. The graph above on the left shows Marindin Profile 13 (Figure 2), which formed a typical erosion profile. The coast eroded an average of 100 meters in 125 years. The graph above on the right shows Marindin Profile 165 (Figure 2), which formed a typical accretion profile. Profiles around the Provincetown Hook accreted sediment, growing an average of 60 meters into the ocean. Erosion of the glacially deposited bluffs has occurred at a faster rate than the formation of new dunes in Provincetown (Figure 1).

Results

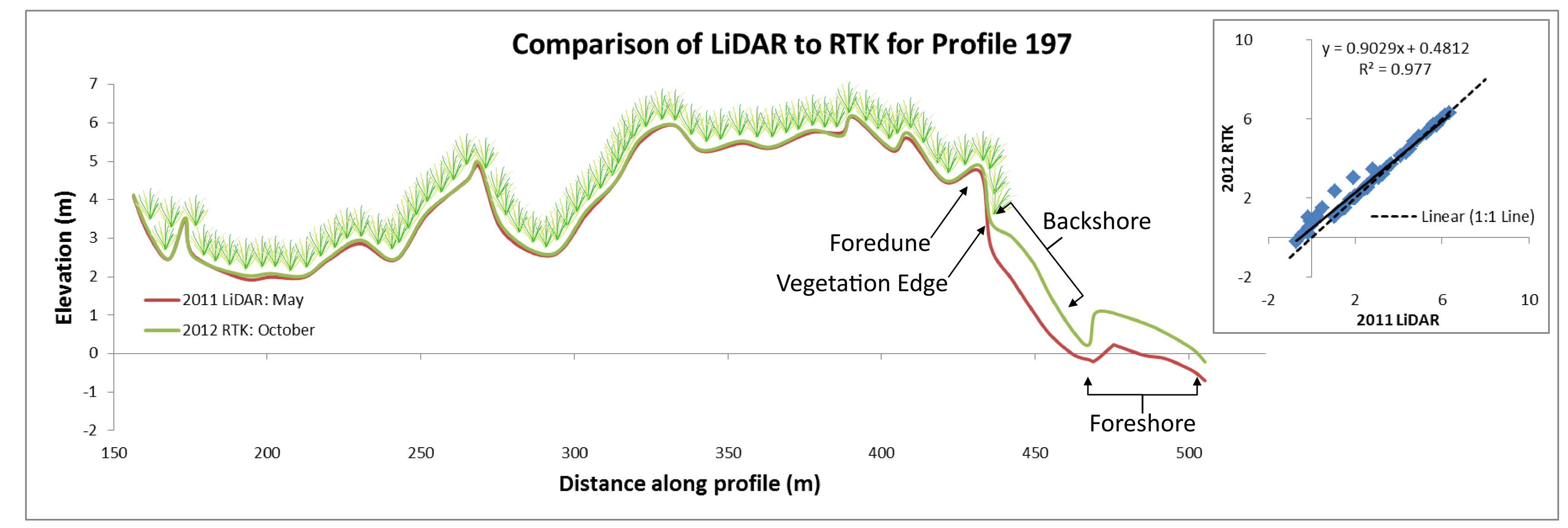


Figure 3: The LiDAR and RTK measurements are in close agreement through the majority of Profile 197 (Figure 2). The roots of the dune grass anchor the sand in place, decreasing erosion. From the edge of the dune vegetation through the foreshore the values do not agree. There is no vegetation on the beach and the waves and wind move the sand, shaping the beach, causing the difference in elevation.

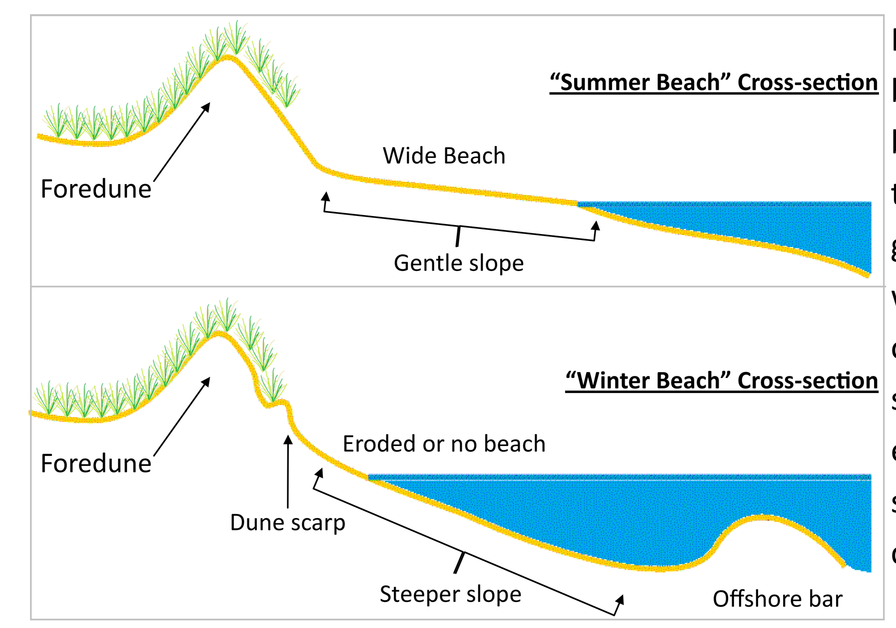
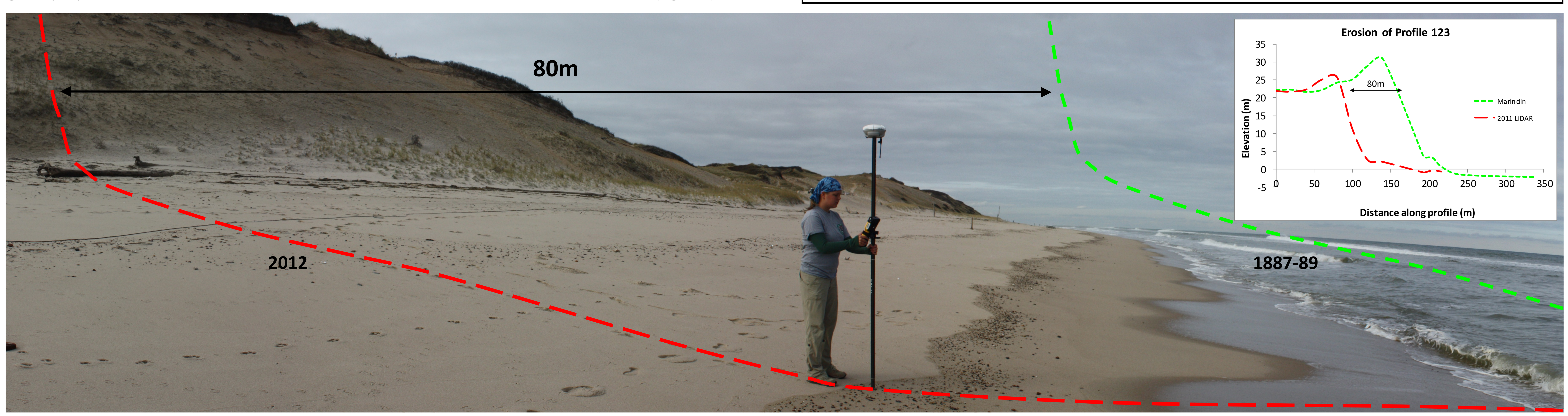


Figure 4 compares a "summer" beach to a "winter" beach. The vegetated dune changes little, but the bare beach is subject to wind and waves. Beaches tend to build outwards during the summer when waves are gentler, reaching their full extent in early fall. Strong winter storms erode beaches, forming steep slopes and offshore bars. Beaches are at their narrowest in late spring. The graph above (Figure 3) shows a real world example of this: the LiDAR data was collected in May, showing a "winter beach", and the RTK data was collected in October, showing a "summer beach".

Conclusions

- LiDAR: large spatial coverage, lower accuracy (±15cm), infrequent flights and expensive.
- RTK GPS: high time resolution (seasonal variation), high accuracy (±5cm), high resolution over small areas, challenging over large areas.
- A combination of RTK GPS and LiDAR offers the best solution for surveys covering large areas.



The author resurveying Marindin profile 123. There has been significant erosion along the coastline of Cape Cod forming bluffs that extend from Eastham to North Truro (Figure 2).

Works cited

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